[0021] **FIGS. 4C and 4D** are graphs showing comparisons of audio signal amplitudes and the amplitude modulation of an RF signal obtained in a similar manner to the graphs shown in **FIGS. 4A and 4B** with the exception that a plywood barrier is interposed between the sound detection system and the aluminum foil; and

[0022] **FIG. 5** is a schematic diagram of an embodiment of a sound detection system in accordance with the present invention that includes an RF source separate from an RF detector.

DETAILED DESCRIPTION OF THE INVENTION

[0023] Embodiments of the present invention use reflected electromagnetic signals to detect audible sound. Pressure waves incident on an object can cause the object to vibrate in a manner indicative of the pressure waves. Electromagnetic radiation reflected by a vibrating object can include an amplitude modulated component indicative of the object's vibrations. Several embodiments of the present invention illuminate objects with an RF signal that does not have a modulated amplitude and extract amplitude modulated information from reflections of the RF signal. In many embodiments, the amplitude modulated information includes information indicative of pressure waves incident on the object. Analysis of the signals indicative of pressure waves can then be performed to reproduce any audible sounds included in the pressure waves.

[0024] Turning now to the diagrams, **FIG. 1** illustrates a sound detection system **10** in accordance with the present invention that includes an antenna **12** coupled via a directional coupler **14** to an RF oscillator **16** and a RF detector **18**. In addition, the RF detector is connected to a digital signal processor **20** which is connected to a speaker **21**. The RF oscillator and the antenna can illuminate an object **24** with an electromagnetic beam **22**. The object typically reflects a portion of the incident electromagnetic signal and the antenna and the RF detector can be used to generate a signal indicative of the amplitude of the reflected signal. The amplitude of the reflected signal may be modulated if the object is vibrating. Information can then be extracted from the signal generated by the antenna and the RF detector by the digital signal processor.

[0025] In the illustrated embodiment, a barrier **26** separates the sound detection system **10** and the object **24**. In addition, two people **28** are conducting a conversation proximate the object. Pressure waves generated as the people speak are incident on the object causing it to vibrate. As indicated above, these vibrations can modulate the amplitude of the RF beam reflections from the object.

[0026] In one embodiment, the reflected signal is received by the antenna, amplified by a low noise amplifier and detected by a total-power direct detector with a bandwidth of at least several 10's of kilohertz to accommodate audio information. A real time digital signal processor can then be used to recover the audio information and convert the audio information to an analog signal for amplification and output to a loud speaker. In several embodiments, signal processing techniques similar to those used with laser sound detection systems can be employed.

[0027] In one embodiment, the sound detection system generates a monochromatic RF beam using a planner antenna having a frequency within the range of 100 MHz to 200 GHz. In other embodiments, the RF beam can have a frequency within the range 1 GHz to 100 GHz. In further embodiments, the RF beam can have a frequency within the range of 10 GHz to 200 GHz As will be discussed below, other antenna configurations can be used such as horn antennas. The frequency of the RF beam can be less than 100 MHz, however, antenna size may increase and the beam may have a width that encompass a very wide field.

[0028] An embodiment of a sound detection system in accordance with the present invention that can be used to detect sound by observing RF reflections from the chest of a human subject is shown in **FIG. 1A**. A sound detection system **10** is shown generating an RF beam **22** that is illuminating the chest of a human subject **28**. The subject's chest reflects the beam and the RF beam's reflections can be amplitude modulated by, amongst other things, a component indicative of any sound being generated by the subject.

[0029] A diagram of a sound detection system in accordance with the present invention is shown in **FIG. 2**. The sound detection system **10'** includes a synthesized RF oscillator **40** that is connected to a common node **42** and a first amplifier **44**. The common node **42** is connected to an oscillator **46** and a lock-in amplifier **48**. The output of the first amplifier **44** is connected to an antenna **50** via a directional coupler **52**. The directional coupler is also connected to a second amplifier **54**. The output of the second amplifier is connected to a mixer **56**. An RF oscillator **58** also provides an output to the mixer. The output of the mixer is connected to the input of a third amplifier **60**. The output of the third amplifier is connected to a bandpass filter **62** and the output of the bandpass filter is connected to a diode detector **64**. An output of the diode detector is connected to an input of the lock-in amplifier **48** and the output of the lock-in amplifier is then provided to a data acquisition computer **66**. In several embodiments, the data acquisition computer includes a speaker. Although the illustrated embodiment uses a lock-in amplifier, the lock-in amplifier may not be necessary as can be seen from the embodiments as discussed below.

[0030] In many embodiments, the RF components of sound detection systems in accordance with the present invention can be fabricated using MMIC technology. Such circuits could cover an area at least as small as several square inches. The RF circuitry can be combined with digital signal processing boards or field programmable gate arrays to perform signal processing functions. The antenna can be constructed using a planar integrated-circuit antenna, such as a microstrip patch array. In one embodiment, an antenna designed for use with a 30 GHz RF signal can be constructed using a patch-array antenna that is approximately 4 inches on a side. Such an antenna can produce a transmitted beam approximately 3 feet wide at a distance of 26 feet. A 3-foot wide beam is typically sufficient to localize a single person or a convenient adjacent reflecting surface. If localization is not an issue, then a similarly small antenna system can be useful up to tens of meters. For situations where the antenna size is not important, a larger array can be used. The effective range of a beam scales approximately with the antenna size and transmitted power. In addition, use of higher frequencies allows for reduced antenna size. Higher frequencies, typically, do not penetrate barriers as effectively as lower frequencies. Reflected signals can be very weak,